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Private Demand for Cholera Vaccines in Hue, Vietnam

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ABSTRACT

Objectives: This study aims to measure the private demand for oral cholera vaccines in Hue, Vietnam, an area of relatively low endemicity of cholera, using the contingent valuation method.

Methods: Interviews were conducted with either the head of household or spouse in 800 randomly selected households with children less than 18 years old. Respondents were asked whether they would purchase an oral cholera vaccine with different levels of effectiveness and durations of effectiveness (both for themselves and for other household members) at a specified price.

Results: The median respondent willingness to pay for 50% effective/3-year vaccine was estimated to be approximately $5, although 17% of the study sample would not pay for a cholera vaccine. The median economic benefit to a household of vaccinating all household members against cholera, as measured by its stated willingness to pay, was estimated to be $40 for a vaccine with these attributes.

Conclusions: The perceived private economic benefits of a cholera vaccine were high, but not evenly distributed across the population. A minority of the people in Hue place no value on receiving a cholera vaccine.

Keywords: cholera, contingent valuation method, vaccine demand, willingness to pay.

Introduction

Through a combination of water and sanitation investments and improved food safety, the threat of cholera infection has been almost completely eliminated in industrialized countries. The disease continues to affect endemic areas in developing countries and causes outbreaks during floods, wars, and other natural and man-made disasters. According to the World Health Organization (WHO), 52 countries reported cholera in 2005, with a total of 131,943 cases and 2272 deaths [1]. These estimates understate the scope of the cholera problem: surveillance is difficult, and many governments underreport known cases for fear of trade and travel sanctions.

There is now a new-generation, internationally licensed vaccine against cholera [2]. This vaccine, developed in Sweden, is a two-dose killed vaccine consisting of inactivated whole cells of *Vibrio cholerae* O1, combined with the B-subunit of the cholera toxin (BS-WC) [3–5]. This vaccine is safe and can provide substantial protection against infection. It offers millions of poor people in developing countries the possibility of reducing their risk of contracting cholera. The study reported here explored what this reduced risk of cholera infection, which a new-generation vaccine can provide, might be worth to people in the city of Hue (population 280,000), Thua Thien Hue Province, Vietnam, from their own perspective.

The average annual incidence of cholera in Vietnam from 1994 to 2002 has been estimated to be 1.71 cases per 100,000 inhabitants [6], but that estimate is uncertain. Historically, Thua Thien Hue Province (where Hue is located) has been one of the high-risk areas for cholera in Vietnam, with outbreaks in 1980, 1983, 1986, 1990, 1992, 1993, and 2003. The 2003 outbreak coincided with our fieldwork for this study. During this 2003 outbreak, 50% of cholera cases were in children less than 18 years old, and the 81 laboratory-confirmed cases were due to El Tor Inaba *V. cholerae* O1.

To address the problem of cholera in Vietnam, in the mid-1980s scientists at the Vietnamese National Institute of Hygiene and Epidemiology worked with a research team from the University of Gothenburg in Sweden to transfer technology for the killed whole-cell cholera vaccine (without the B-subunit) [7]. This vaccine was similar but not identical to the oral killed whole-cell cholera vaccine (without the B-subunit) that

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had been found to confer 50% protection for 3 years in a randomized, placebo-controlled trial in Bangladesh [3,4].

A two-dose regimen of the locally produced, first-generation Vietnamese vaccine was tested in an open, controlled field trial in Hue in the early 1990s and was found to confer 66% protection during an outbreak of El Tor Ogawa cholera 8 to 10 months after vaccination [7]. The duration of protection provided by the Vietnamese oral cholera vaccine is not known, but if similar to the Swedish vaccine, it would be approximately 3 years [4]. Production costs for the Vietnamese vaccine are low due to the decision not to include the expensive toxin B-subunit in the vaccine. The vaccine is delivered pre-emptively from May through October to children in districts predicted to have a high incidence of cholera and to all age groups in areas experiencing an outbreak. In Vietnam, only a very small proportion of the population pays private sector providers for non-Expanded Program Immunization (EPI) vaccines against diseases such as rabies, hepatitis B, Japanese encephalitis, and varicella. These vaccines are generally not available through the national immunization program and can only be obtained in a few locations, typically in large cities.

In 1998, a mass vaccination campaign against cholera targeting nonpregnant residents more than 2 years of age was conducted in Hue using two doses of locally produced oral killed bivalent whole-cell cholera vaccine. The total cost per fully vaccinated person in 1998 was estimated to be approximately $1, excluding the costs of foreign expatriate assistance and the value of time that households spent obtaining the vaccine [8]. This mass vaccination program provided an opportunity to assess operational logistics, public sector costs, and vaccination coverage, but no attempt was made to estimate the economic benefits of this cholera vaccine.

In the summer of 2003, we interviewed individuals in Hue, asking whether they would purchase a (hypothetical) cholera vaccine for themselves and for other household members if it were available to them at a specified price. Each respondent was assigned a cholera vaccine of certain effectiveness and duration and a single price; overall the survey design covered two levels of effectiveness, two levels of duration, and five possible prices. The array of responses allowed us to investigate how private household demand for cholera vaccines changed with variations in the vaccine characteristics mentioned earlier. This "stated preference" approach, termed the contingent valuation (CV) method, has been widely used to estimate household demand for environmental and infrastructure services in both industrialized and developing countries [9–12]. Researchers have also used CV surveys to estimate private demand for vaccines that protect against other diseases, such as malaria [13,14], HIV/AIDS [15,16], and typhoid fever [17].

The present study was the first to use CV methods to estimate the private economic benefits of a cholera vaccine. There are a few studies in the literature that have attempted to estimate the cost-effectiveness of cholera vaccination interventions in different settings, but such calculations do not require estimates of the economic benefits of cholera vaccines [18,19]. Cookson et al. [20] estimated the economic benefits of cholera vaccines as part of a cost–benefit analysis of a possible vaccination program in northern Argentina. They estimated the economic benefits of cholera vaccination using medical costs of illness avoided as a measure of benefits, and reported a cost of illness per case of $602. This estimate, however, includes very high managerial costs based on bimonthly transport of medical personnel to the cholera outbreak areas by helicopter (some patients were also evacuated by helicopter). Their conclusions that cholera vaccination passes a cost–benefit test cannot be assumed to apply in South or South-east Asia or Africa, where treatment costs are much lower.

Our study had three main objectives. The first was to estimate how the price, effectiveness, and duration of the vaccine would affect individuals' decisions to purchase a cholera vaccine for themselves. The second was to estimate how many vaccines of a specified effectiveness, duration, and price an individual would purchase for other household members. The third was to estimate individuals' and households' willingness to pay (WTP) for cholera vaccines of different levels of effectiveness and different durations.

We believe that information about the private demand for cholera vaccines is important to health policy decision-makers, even though most governments in Asia are willing and able to provide free cholera vaccines to curb major cholera outbreaks. Cholera infection does not occur only during outbreaks; endemic cholera remains a problem in many countries. In Vietnam, cholera is largely episodic, but these outbreaks occur often. It is thus rational for some individuals to not want to wait for the government to declare an emergency before seeking out protection against infection. The reality is that governments do not make new-generation cholera vaccines widely available to individuals who are willing to pay for them, often on the grounds that there is no private demand. In this article, we show that private demand may be significant in some places and that individuals should not necessarily have to wait for the government to declare an official cholera outbreak before they can protect their families.

This article presents a summary of our research methods and field procedures, as well as results of our analysis of the data collected in our CV survey. The analysis and results address both respondent and

household demand and WTP. Our closing discussion reviews the varying degrees of interest in cholera immunization revealed by our results, and comments on the general prospects for a user-supported cholera immunization program in Hue.

Methods

Our research design and field procedures for this study of cholera vaccine demand followed the protocols used in a companion study of private demand for a typhoid vaccine, conducted in Hue in 2002 by the same research team [17]. In this cholera vaccine demand study, a random sample of 1399 households with children aged less than 18 years was selected from six communes in Hue (five urban and one semiurban). Within each household, either the head of household or spouse was randomly selected to be interviewed; respondents were required to be less than 65 years of age. The response rate was 57%. Refusals were very few, but it proved difficult to find and make appointments with some respondents. Ultimately, 800 in-person interviews were completed.

The research team worked in close collaboration with both local and foreign public health experts to develop the CV survey instrument. Three pretests of the survey instrument were conducted in June 2003 to refine the language and to determine the set of vaccine prices to offer. The final survey was conducted in July 2003. The average individual interview took 45 minutes to complete. Each interview proceeded as follows.

After assessing the respondent's knowledge and attitudes about cholera and vaccination, the enumerator provided the respondent with information about the causes and symptoms of cholera. The concept of vaccine effectiveness was explained to the respondent through a technique developed by Suraratdecha et al. [16]. The respondent's understanding of the concept of vaccine effectiveness was then tested. If the respondent answered the test questions incorrectly, the enumerator explained the concept again and the respondent was retested. Regardless of whether the test questions were answered correctly on the retest, the interview proceeded. Most respondents (79%) understood the concept of vaccine effectiveness after it was explained to them once, and did not need a retest. An additional 12% understood the concept after it was explained a second time, and passed the retest. The rest of the respondents (9%) could not grasp the concept of vaccine effectiveness and failed both the first test and the retest. These respondents tended to be older women with low education and low income. These respondents were also more likely to be from semiurban communes.

The enumerator then presented to the respondent a description of a cholera vaccine. The vaccine described had been randomly preassigned to that respondent from an array of four possible types whose attributes varied in terms of duration and effectiveness. The least protective hypothetical vaccine was 50% effective for 3 years; the most protective was 99% effective for 20 years. The other two vaccine types (70% effective for 20 years, 70% effective for 3 years) fell between those two extremes. (The 50%/3-year vaccine is closest to the characteristics of the locally produced oral cholera vaccine in Vietnam.) Each of the four hypothetical vaccine types was available at five prices: 5,000, 25,000, 50,000, 200,000, and 500,000 Vietnamese Dong ($0.33, $1.67, $3.33, $13.33, $33.33). These prices were selected on the basis of pretest results suggesting that this range included the majority of the study population's WTP values for a single vaccine. The pretest results showed that most people would agree to pay the lowest price and that almost everyone would reject the high price.

The enumerator then asked the respondent whether he or she would choose to purchase the vaccine described at that price for his or her own immunization. Each respondent was asked about only one vaccine type at a single price. Respondents who refused to pay the offered price were asked why they would not pay and whether they would accept the vaccine for free. Next the respondent was asked how many vaccines (with these same characteristics and price) he or she would purchase for other household members, and for whom in the household these vaccines would be purchased.

At the end of the interview the enumerator asked the respondent how certain he or she was of the answer given to the vaccine purchase question. A substantial majority (82%) said they were "very certain"; only 2% said they were unsure of their answer. Enumerators were asked to assess the quality of the interview immediately after completing each survey. Most of the enumerators (97%) indicated that they believed that the information they had obtained from the respondent was reliable.

Five respondents' interview responses had to be excluded from our data analysis because their answers indicated that they thought that the hypothetical cholera vaccine described to them would not be safe, even though they had been asked, for our purposes, to assume that it was safe. Thus, the final sample size available for the analysis was 795.

Statistical Analysis

Because 17% of the sample was out of the market, a spike model was used to analyze the respondent demand for the cholera vaccine. The spike model is a general model for dichotomous choice CV data that accounts for a mass of observations at zero when estimating model parameters and calculating WTP

estimates [21,22]. In contrast to assuming that all respondents have a positive WTP, the spike model allows for corner solutions that arise because the vaccine does not contribute to utility [21]. We estimate a spike model using parametric maximum likelihood methods. The spike model uses responses to two questions: The first is whether the respondent is willing to purchase a vaccine at the given price and then whether the respondent would take a free vaccine. The second question is posed only if the response to the first is "no." If the response to both questions is "no," the respondent is assumed to be out of the market and have zero WTP. Otherwise, the respondent is in the market. The log likelihood function is

$$\ln L = \sum_{N=1}^{i} \delta_1\delta_2 \ln[1 - f(p_v)] + \delta_1(1-\delta_2)\ln[f(p_v) - f(0)] + (1-\delta_1)\ln[f(0)] \quad (1)$$

where $f(\cdot)$ is the distribution of WTP; δ_1 is an indicator that takes the value of 1 if the individual is in the market (0 otherwise); and δ_2 takes the value of 1 if the respondent would pay the vaccine price, p_v (0 otherwise) [21]. In a multivariate context, we assume $f(\cdot)$ is a function of a vector of individual- and household-specific explanatory variables. The mean WTP in this simple spike model is given by Eq. 2, where X is the vector of explanatory variables, β is the vector of parameters estimated by maximizing the likelihood function, and β_p is the estimated parameter for vaccine price:

$$-\frac{1}{\beta_p}\ln[1 + \exp(X\beta)] \quad (2)$$

Household demand is estimated using a count model. The simplest count model assumes that the dependent variable, the number of vaccines the respondent said he would purchase (A_i^*), is a random draw from a Poisson distribution with a mean λ_i. Here λ_i is a function of a vector of parameters (β) and a vector of individual- and household-specific explanatory variables (X_i). This relationship can be written as $\lambda_i = \exp(X_i\beta)$, where the exponential specification is used to restrict λ_i to be positive. The probability of observing household i purchasing A_i^* vaccines is

$$P\left[A_i^* = k_i\right] = \frac{\exp(\lambda_i)\lambda_i^k}{k_i!} \quad (3)$$

where $k_i = 1,2,3 \ldots$ and $\lambda_i = \exp(X_i\beta)$.

Because the respondent would not state that he or she would purchase more vaccines than there are people in his or her household, the count data model is modified to condition the probability of an observed outcome on household size. In the modified model, which we refer to as the truncated Poisson model, the probability density function is modified, so that the household size is an upper bound for each observation.

$$P\left[A_i^* = k_i \middle| A_i^* \le n_i\right] = \frac{e^{\lambda_i}\lambda_i^k / k_i!}{\Pr\left[A_i^* \le n_i\right]} \quad (4)$$

where $k_i = 1,2, \ldots n_i$

These models yield convenient expressions for WTP, which is the area under the household demand curve between zero and n. Assuming the vaccine is provided for free,

$$WTP_i = -\frac{e^{X_i\beta}}{\beta_p} \quad (5)$$

Results

Socioeconomic and Demographic Characteristics of the Sample Respondents

Table 1 presents summary statistics of the socioeconomic and demographic characteristics of the 800 respondents in the sample. Most of the households surveyed were in an urban area. The typical household had three adults and two or three children. Male and female respondents were fairly evenly represented; the average age was about 45 years. Although a modest majority of respondents (59%) had completed secondary school, 26% of respondents reported that they had difficulty reading a newspaper. The average self-reported monthly household income was $103. Households were, on average, only 12-minutes walking distance from the nearest private health facility and approximately the same distance from the nearest public Preventive Medicine Center.

Knowledge, Experience, and Risk Perception Regarding Cholera and Vaccination

A large majority of respondents (90%) reported that they knew about cholera, and most thought that cholera is especially serious for children less than 5 years of age and for pregnant women. Comparatively few (7%) reported that a household member had had cholera (33% of those cases were children), and not very many (11%) claimed to have known someone personally, other than a household member, who had been infected with the disease. A much larger number (50%) thought that one of their children would be "somewhat" or "very likely" to contract cholera sometime in the future.

Almost all respondents (94%) knew about vaccines, but only 58% reported that they had ever been vaccinated before, against any disease. Virtually all (98%) respondents, however, reported that some or all of their children had received the EPI vaccinations. Not quite half (43%) of the sample households had at least one member who had been vaccinated for cholera during the 1998 or 2000 mass cholera vaccination campaigns, and 98% of those respondents said they were "satisfied" with the cholera vaccine that had been

Table 1 Variable definition and descriptive statistics

Variable	Description	Mean (SD)
Demographic and socioeconomic		
Respondent's residence	1 if urban commune; 0 if semiurban commune	0.84
Male respondent	1 if male	0.41
Age of respondent	Continuous (in years)	45 (9)
Education	edu1 = 1 if never attended school	0.07
	edu2 = 1 if completed 1–5 years of school	0.23
	edu3 = 1 if completed 6–12 years of school	0.59
	edu4 = 1 if university or postgraduate degree	0.11
Household size	Number of household members (continuous)	5.4 (1.8)
Household income	Monthly household income (continuous, in $)	103 (86)
Water connection	1 if household has own private or shared water connection	0.89
Averting behavior		
Washes hands before eating	1 if respondent reported "always" washing hands before eating	0.65
Boils water before drinking	1 if respondent reported "always" boiling drinking water	0.95
Time from house to the nearest private health facility on foot	Distance from house to the nearest private health facility on foot (in minutes)	12 (10)
Risk		
Risk of getting cholera for self	1 if "somewhat likely" or "very likely" that respondent would get cholera sometime in the future	0.45
Risk of getting cholera for children	1 if "somewhat likely" or "very likely" that children in the household would get cholera sometime in the future	0.50
Respondent feels cholera is common in his/her commune	1 if respondent reported cholera is common in his/her commune	0.02
Knowledge and experience		
Knows someone who has had cholera	1 if respondent knows someone who has had cholera	0.11
Someone in household has had the oral cholera vaccine in the past	1 if anyone in the household (including respondent) has had the oral cholera vaccine in the past	0.43
Efficacy test		
Respondent failed vaccine efficacy test twice	1 if failed both rounds	0.09
Vaccine attributes		
99% effective/20-year	1 if vaccine is 99% effective for 20 years; 0 otherwise	0.26
70% effective/20-year	1 if vaccine is 70% effective for 20 years; 0 otherwise	0.25
70% effective/3-year	1 if vaccine is 70% effective for 3 years; 0 otherwise	0.24
50% effective/3-year	1 if vaccine is 50% effective for 3 years; 0 otherwise	0.25

received. Approximately half (47%) of the respondents reported that they alone would be primarily involved in deciding whether other household members would receive a vaccine; 34% reported that both the respondent and the spouse would make the decision together.

Respondent Demand for Cholera Vaccines

Table 2 shows that as the price increases, the percentage of respondents who said they would buy the vaccine declines, for each of the four hypothetical vaccine types that were offered in our survey. A small percentage (5–20%) said they would purchase the cholera vaccine for themselves even at the two highest prices ($13.33 and $33.33). A substantial number said they would be unwilling to purchase a cholera vaccine for themselves at the single (preassigned) price offered. Of these, some indicated that they would be willing to accept the vaccine if offered free of charge; others would not take the vaccine even if offered free of charge. We classified all respondents who refused both the bid and the free vaccine as "out of the market." In aggregate, they represent 17% of our total sample.

Most respondents (96%) who said they would purchase a cholera vaccine for themselves stated that they

Table 2 Percentage of respondents who said they would purchase a cholera vaccine for themselves at the price offered

Price ($)	n	Yes	No	% of Yes
99%/20-year				
0.33	41	38	3	93
1.67	39	18	21	46
3.33	40	19	21	48
13.33	40	5	35	13
33.33	40	4	36	10
70%/20-year				
0.33	39	34	5	87
1.67	40	19	21	48
3.33	40	15	25	38
13.33	40	4	36	10
33.33	40	7	33	18
70%/3-year				
0.33	40	32	8	80
1.67	41	18	23	44
3.33	40	16	24	40
13.33	40	5	35	13
33.33	40	3	37	8
50%/3-year				
0.33	40	31	9	78
1.67	40	22	18	55
3.33	40	12	28	30
13.33	40	8	32	20
33.33	40	2	38	5

Table 3 Nonparametric and parametric estimates of respondent and household WTP ($) for different cholera vaccines

	Respondent WTP					Household WTP
	Full sample (n = 795)			Excluding "out of market" respondents (n = 650)		Full sample (n = 795)
	Nonparametric		Parametric	Nonparametric		Parametric
Vaccine type	Turnbull lower-bound	Kristrom midpoint	Spike model	Turnbull lower-bound	Kristrom midpoint	Truncated Poisson model
99%/20-year						
Mean	4.5	7.1	7.4	5.1	8.1	50
Median	0.3–3.3	0.3–1.7	6.5	3.3–13.3	3.3–13.3	49
70%/20-year						
Mean	3.0	5.9	6.4	3.8	7.6	46
Median	0.3–1.7	0.3–1.7	5.2	3.3–13.3	3.3–13.3	44
70%/3-year						
Mean	4.4	6.6	6.3	5.3	8.2	40
Median	0.3–1.7	0.3–1.7	5.0	1.7–3.3	1.7–3.3	39
50%/3-year						
Mean	4.5	6.9	6.3	6.0	9.2	40
Median	1.7–3.3	1.7–3.3	5.0	1.7–3.3	1.7–3.3	37

WTP, willingness to pay.

would do so because they thought the vaccine would be useful for prevention and safety. Of those who were unwilling to buy a vaccine at the price offered, 76% said they would not do so because it was too expensive or because they had no money. Approximately half (50%) of those would not accept a vaccine free of charge said that they did not believe that they had any chance of becoming infected with cholera. All of these data suggest that respondents were giving thoughtful, reasoned answers to the questions posed to them.

The data in Table 2 were used to calculate nonparametric estimates of mean and median respondent WTP using two different estimators: Turnbull lower-bound and Kristrom's midpoint [23]. The WTP results for all four vaccines for both estimators are presented in Table 3 for the total sample (second and third columns) and also only for the respondents who were "in the market" (restricted sample; fifth and sixth columns). As expected, the Turnbull lower-bound WTP estimates are less than the estimates for Kristrom's midpoint estimator, for both the full and the restricted sample, and the estimates for the full sample are less than the estimates for the restricted sample, for both estimators. The nonparametric estimates of mean respondent WTP ranged from $3.0 for the 70%/20-year vaccine for the full sample, to $9.2 for the 50%/3-year vaccine for the restricted sample. Median WTP estimates ranged from $0.3 to $1.7 for the 70%/3-year vaccine for the full sample, to $3.3 to $13.3 for the 99%/20-year vaccine for the restricted sample. These nonparametric estimates suggest that respondent WTP is insensitive to changes in vaccine effectiveness and duration [24,25].

Table 4 presents the results for our preferred specification of the spike logit model to investigate the determinants of individuals' decisions whether to purchase the oral cholera vaccine for themselves at the price offered. Seven explanatory variables are statistically significant and their coefficients have the expected signs. In the model, respondents are more willing to purchase a cholera vaccine for themselves when 1) the price of the vaccine is low; 2) the household income is high; 3) they have more than secondary-level education; 4) they are young; 5) they perceive themselves to be at some risk of getting cholera in the future; and 6) they know someone who has been infected with cholera. These results generally support the construct validity of the respondents' answers to the CV (WTP) questions. Results for vaccine effectiveness and duration were, however, not statistically significant, suggesting that respondents had difficulty distinguishing the comparative value of vaccines with different degrees of effectiveness and duration [24].

Using the estimated parameters from this spike logit model, we calculated the mean and median WTP estimates for the four different vaccine types (Table 3). The mean WTP of the average respondent for a 99%/20-year cholera vaccine is $7.4, higher than that for the other three types ($6.3–$6.4). The spike logit estimates of the median WTP ranged from $5.0 for the 50%/3-year vaccine to $6.5 for the 99%/20-year vaccine. These spike logit WTP estimates are approximately 20% higher than the lower-bound Turnbull WTP estimates for the full sample.

Household Demand for Cholera Vaccines

Table 5 presents household demand for cholera vaccines in terms of respondents' willingness to purchase a vaccine of the preassigned type and price either 1) for all household members (including the respondent); or

Table 4 Determinants of respondents' and household demands for a cholera vaccine (multivariate results)

	Respondents' demand model: Spike logit model (n = 795)		Household demand model: Truncated Poisson model (n = 795)	
Independent variable	Coefficient	$P > z$	Coefficient	$P > t$
Price of vaccine	–0.24	0.00†	–0.10	0.00†
Vaccine 99% effective/20-year	0.32	0.14	0.19	0.00†
Vaccine 70% effective/20-year	0.05	0.80	0.05	0.34
Vaccine 70% effective/3-year	0.03	0.88	–0.03	0.56
Resides in urban commune	0.23	0.26	0.35	0.00†
Male respondent	–0.04	0.83	0.08	0.05*
Household income	0.01	0.00†	0.003	0.00†
Water connection	0.10	0.69	0.21	0.00†
Boils water	–0.15	0.66	–0.32	0.00†
Washes hands before eating	–0.01	0.97	0.15	0.00†
Time from house to the nearest private health facility on foot (minutes)	0.00	0.12	0.005	0.00†
Primary education (1–5 years)	0.47	0.13	0.05	0.52
Secondary education (6–12 years)	1.13	0.00†	0.63	0.00†
Completed university	1.04	0.01†	0.90	0.00†
Age of respondent	–0.03	0.00†	–0.01	0.00†
Respondent feels cholera is common in his/her commune	0.49	0.38	0.07	0.61
Respondent believes it somewhat or very likely that she/he would get cholera some time in the future.	0.31	0.05*	–0.20	0.01*
Respondent believes it somewhat or very likely that children in the household would get cholera some time in the future.			0.44	0.00†
Knows someone who has had cholera	0.77	0.01†	0.44	0.00†
Someone in household has had the oral cholera vaccine in the past	0.19	0.24	0.12	0.00†
Failed vaccine efficacy test	0.21	0.46	0.09	0.21
Household size	–0.03	0.52	–0.01	0.48
Constant	0.76	0.25	0.66	0.00†
Log likelihood	–779		–1352	

*5% significance level, two-tailed test.
†1% significance level, two tailed test.

2) for none (including the respondent). As shown, at the lowest price offered ($0.33 per vaccine), a substantial proportion of respondents would purchase a vaccine for all household members (63% for the 70%/3-year vaccine; 80% for the 99%/20-year vaccine). At the highest price ($33.33), very few agreed to purchase a vaccine of any type for all household members (0% for the 50%/3-year vaccine; 8% for the 99%/20-year vaccine). At the lowest price, most respondents (79–98%) did want to purchase at least one vaccine for some members of their household. At the highest prices ($13.33 and $33.33), the majority of respondents (68–85%) said they would not purchase the vaccine for anyone in their household.

Figure 1 shows how the number of cholera vaccines an average household would purchase varies with the price, effectiveness, and duration of the vaccine, on the basis of a simple tabulation of the survey results without covariates (for the 634 sample households with fewer than seven members). At the highest prices ($13.33 and $33.33), the typical respondent would buy either zero or one vaccine for the entire household. If the price of the vaccine were to fall to $3.33 or $1.67, the typical respondent would purchase about two vaccines (the average household in this subsample had 4.6 members). At the lowest price ($0.33), the average respondent would purchase about four vaccines, that is, a vaccine for almost everyone in the household.

To identify determinants of household demand for the four cholera vaccine types, we estimated a truncated Poisson model in which the dependent variable is the total number of vaccines that the respondent would purchase for the household [14]. As with our spike logit model of respondent demand, the independent variables for household demand describe the characteristics of the vaccine (price, effectiveness, duration), the socioeconomic characteristics of the respondent's household, and attitudes and perceptions about cholera and vaccination. The results for our preferred model specification are presented in Table 4.

Table 5 Percentage of respondents who would purchase vaccines for everyone/no one in the household, by vaccine type and price

Price	99%/20-year	70%/20-year	70%/3-year	50%/3-year
Would purchase vaccines for all household members				
$0.33	80%	64%	63%	67%
$1.67	33%	38%	30%	43%
$3.33	28%	28%	28%	15%
$13.33	10%	8%	5%	15%
$33.33	8%	3%	5%	0%
Would not purchase any vaccines for household members				
$0.33	2%	8%	15%	21%
$1.67	31%	40%	45%	30%
$3.33	40%	38%	44%	60%
$13.33	78%	80%	85%	68%
$33.33	83%	80%	83%	85%

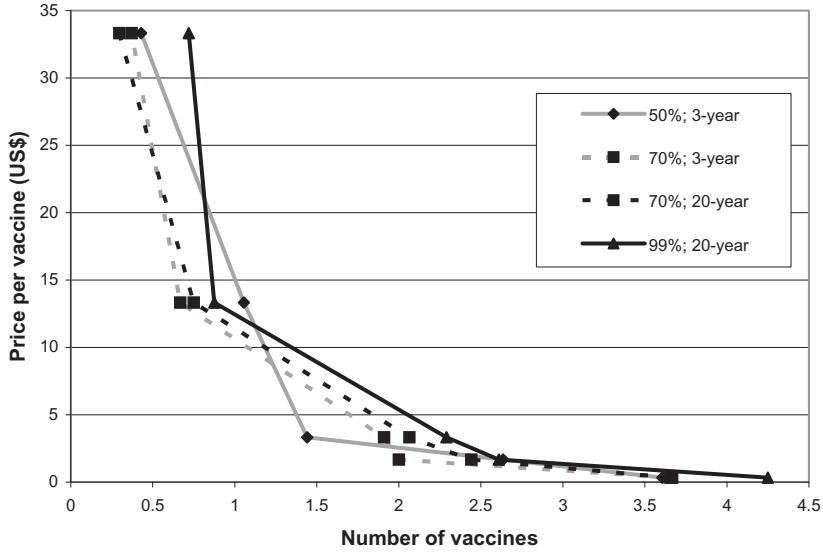

Figure 1 Average number of cholera vaccines respondent would purchase for household members by price of the vaccine (for households with fewer than seven members; n = 634).

As expected, the price of the vaccine had a negative and statistically significant effect. Demand for the 99%/20-year vaccine was higher than for the other three vaccine types, a result statistically significant at the 99% level. The results indicate, however, that respondents did not value the other three vaccines differently, that is, demand for the 50%/3-year vaccine was not statistically different from demand for the 70%/3-year vaccine or for the 70%/20-year vaccine.

As with the spike logit model of respondent demand, all of the key socioeconomic and attitudinal determinants of vaccine demand in the household model are statistically significant. Household income and the education of the respondent all have a positive and statistically significant effect on vaccine demand. Older and male respondents would buy fewer vaccines. People living in urban communes would purchase more vaccines than people in semiurban areas. Respondents who thought that someone in their household was "somewhat likely" or "very likely" to contract cholera in the future, and who knew someone who had had cholera, stated that they would purchase more vaccines.

The last column in Table 3 reports the mean and median household WTP estimates from the truncated Poisson regression models for the four different vaccine types. These estimates represent the private economic benefits that would accrue to the average household if all household members were vaccinated against cholera free of charge. As anticipated, household WTP estimates are largest for the 99%/20-year vaccine (mean $50) and second largest for the 70%/20-year vaccine (mean $46). Estimates of household WTP for the 70%/3-year vaccine and the 50%/3-year vaccine are similar in magnitude (mean $40). The parameter estimates from this truncated Poisson regression were used to calculate the average household WTP for a 50%/3-year cholera vaccine for households with different characteristics (Table 6). The mean household WTP is $15 higher among urban households than semiurban households ($43 vs. $28). Households in the highest monthly income quartile are willing to pay about $30 more for vaccines than households in the lowest household income quartile ($60 vs. $30). The mean WTP for households with school-aged children is only $4 higher than that for households without school-aged children ($41 vs. $37).

Vaccine Coverage versus Vaccine Price

Using these models, we simulated what would happen if the cholera vaccine were made easily available to residents of Hue and different prices were charged for vaccination. Vaccine coverage is slightly higher for the 99%/20-year vaccine than for the other three vaccines. The model results suggest that approximately half of the city's population would choose to be vaccinated with the 50%/3-year oral cholera vaccine if the two-dose regime were made available at a price of $1. These findings suggest that there is potential for recovering a portion of the costs of a cholera immunization program from direct user fees. Moreover, 50% cover-

Table 6 Average household WTP ($) for 50%/3-year vaccine, by household characteristics

Household type	n	Mean WTP
Urban	665	$43
Semiurban	131	$28
Low-income (1st quartile)	134	$30
Middle-income (2nd and 3rd quartiles)	454	$37
High-income (4th quartile)	208	$60
With school-aged children	796	$41
Without school-aged children	66	$37

WTP, willingness to pay.

age would probably induce substantial herd immunity benefits for both the unvaccinated and the vaccinated individuals [26].

Discussion

Our study suggests that for a household in Hue the median economic benefit of vaccinating all household members against cholera, as measured by the household representative's (respondent's) stated WTP, is on the order of $40 for a vaccine that is 50% effective with a 3-year duration. These high perceived economic benefits exist even though most respondents already have improved water and sanitation services, boil their drinking water, and have in the past received vaccines free of charge. The respondents are familiar with vaccines and stated that they were quite certain of their answers to the vaccine purchase questions posed to them. Demand for a cholera vaccine in Hue, an area of relatively low endemicity for cholera may have been influenced by the small cholera outbreak that occurred during the course of our fieldwork in the summer of 2003, although we expect this effect was minimal. The total number of cases in the outbreak was only 81 in a city of 280,000 people, and very few respondents mentioned the outbreak during the interviews.

Respondents' demand for all four types of the hypothetical cholera vaccine offered in our survey design was strongly affected by the price of the vaccine. It is not clear, however, whether respondents answered differently depending on which of the four preassigned vaccine types they were offered. One would hypothesize that at high vaccine prices, respondents who were offered the 99% effective/20-year (most protective) vaccine would want to buy more vaccines than respondents who were offered the 50% effective/3-year (least protective) vaccine. At low vaccine prices, it is unclear how differences in vaccine type (level of effectiveness and duration) affected respondents' willingness to pay for the vaccine offered. This is because demand for a vaccine is limited by the size of the respondent's household. At the lowest price offered ($0.33 per vaccine), a majority of respondents would purchase a cholera vaccine for all household members. If a respondent wanted to purchase a 70% effective/3-year vaccine with a price of $0.33 for everyone in the household, we would not expect them to agree to purchase more vaccines if they were offered a 99% effective/20-year vaccine at the same price.

Although the perceived private economic benefits of a cholera vaccine are high, they are not evenly distributed across the population. A minority of the people we interviewed in Hue placed no value on receiving a cholera vaccine, but a small minority appeared to value it very highly. A skewed distribution of perceived private economic benefits is in fact characteristic of many goods and services, not just vaccines, but it is inconsistent with the image of the economic benefits of vaccines that is prevalent among public health professionals. Because a vaccine has essentially the same effectiveness and duration for almost all individuals, it is commonly assumed that the vaccine's economic benefits to individuals with the same risk of infection would be similar. The stated preference (CV) results presented here suggest that similar individuals may perceive the private economic benefits they would receive from a cholera vaccine quite differently. Individuals not only may have different perceptions of the risk of becoming infected with cholera, but they also may value the risk reduction offered by a cholera vaccine differently.

This heterogeneity in preferences for risk reduction resulted in widely different estimates of the economic benefits of vaccination across our study population in Hue. This conclusion must be qualified, however, because the skewed distribution of respondent WTP estimates may have been heavily influenced by a small number of respondents who agreed to purchase the vaccine at the highest prices offered, not because they wanted the vaccine at that price but because they said "yes" to please the enumerator in an in-person interview. The mean WTP estimates from CV surveys are especially sensitive to such yea-saying and enumerator bias; thus we consider the median WTP estimates to be more robust and interpretable with greater confidence. In previous studies, we found that giving respondents time to think about vaccine purchase decision appears to be an effective means of reducing yea-saying and helping respondents give more realistic (lower) estimates of their actual vaccine demand [27]. Because respondents in this study were not given time to think about their purchase decisions, we consider the estimates presented here to be upper-bound estimates on both respondent and household vaccine demand and WTP.

The uneven distribution of both respondent and household WTP estimates across households in Hue has important implications for the design of cholera vaccination programs there and for any attempt to recover the financial costs of vaccine provision. Our results suggest that there is in fact a significant private market for cholera vaccines in Hue. It appears that if cholera vaccines were made easily available through private market channels, a substantial minority of households would be willing to spend a few US dollars to vaccinate some of their members. Nevertheless, a mass vaccination campaign that attempted to recover financial costs would need to charge very low prices to ensure widespread coverage. We estimate that about 17% of the population has no interest in being vaccinated and would not pay any amount for a cholera vaccine.

It is important to emphasize that our estimates of the private economic benefits of a cholera vaccine as perceived by individuals themselves are an incomplete

estimate of the economic benefits of a cholera vaccination program. A large cholera outbreak would not only paralyze the health-care system, but would also have serious macroeconomic consequences, particularly in regions where tourism is an important economic sector. It is beyond the scope of this research to estimate the macroeconomic consequences of cholera outbreaks. Our research is more applicable to cholera-endemic areas than to situations with large-scale epidemics.

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